Long-term Cryogenic Propellant Storage for the TOPS Mission

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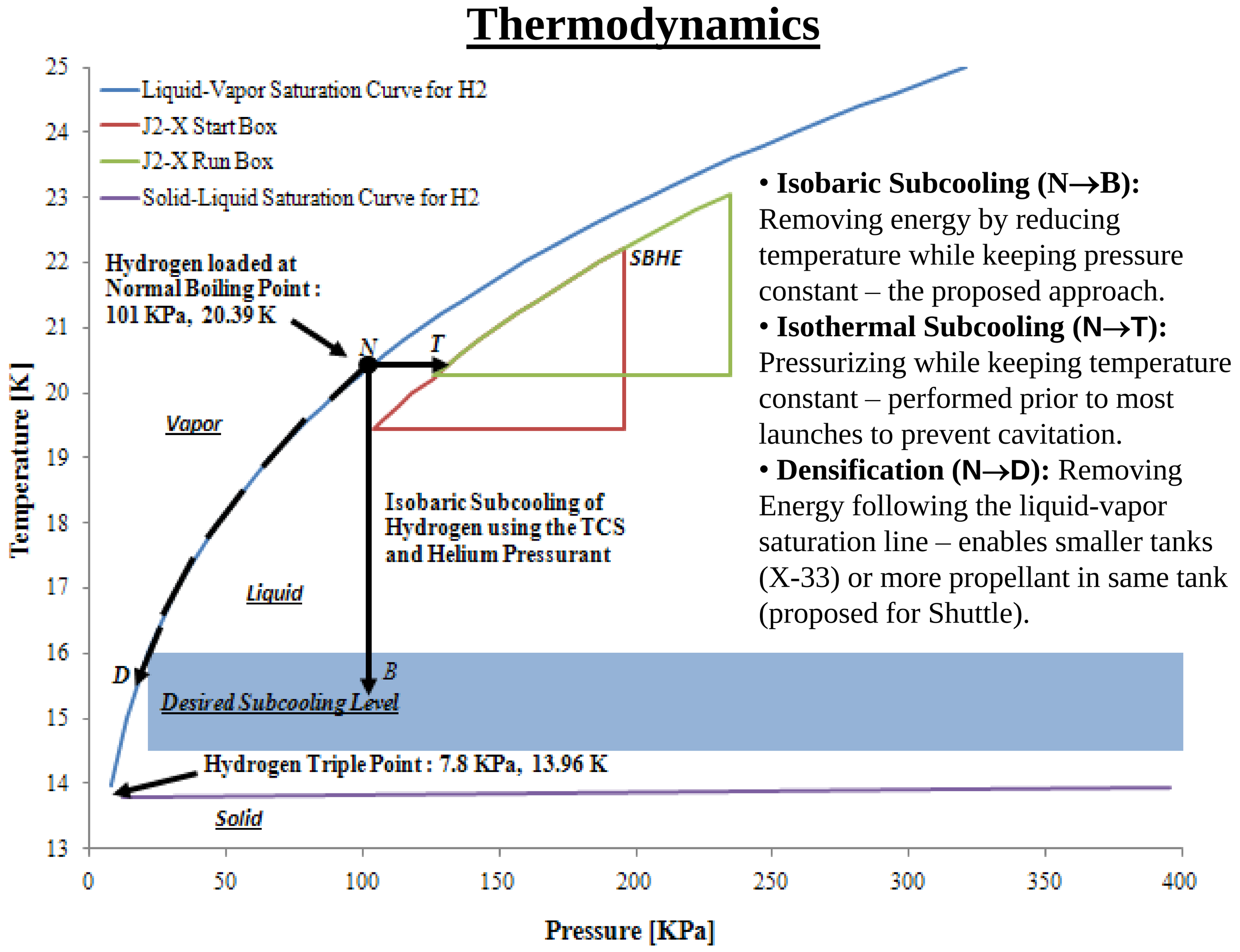
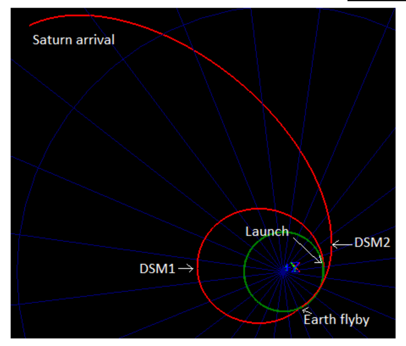
Motivation

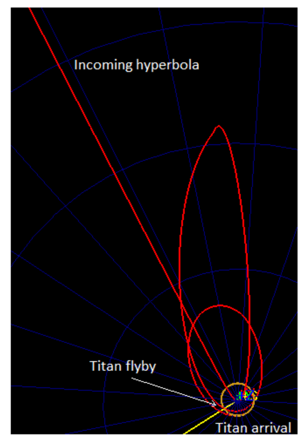
- Liquid Hydrogen (LH2) and Liquid Oxygen (LO2) provide the highest specific impulse of any practical chemical propulsion system. → Highest payload mass fraction.
- NASA is working on several passive, active, and fluid conditioning strategies for long duration in-space storage of cryogenic propellants.
- Subcooling liquid hydrogen prior to launch will triple the in-space vent-free hold time without adding any significant launched mass.
- Mission Design Laboratory (MDL) study of a representative mission to Titan: Titan Orbiter Polar Surveyor (TOPS).
- TRL Increase in Launchpad Cryogen Subcooling Heat Exchanger Hardware.

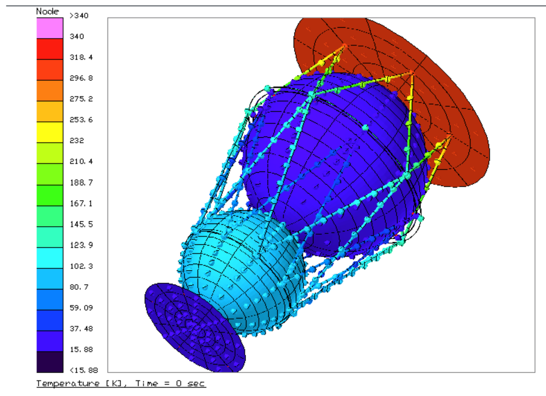
Thermodynamics

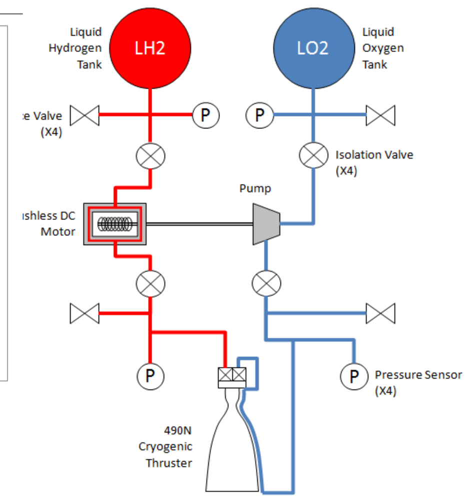


Titan Orbiter Polar Surveyor (TOPS)

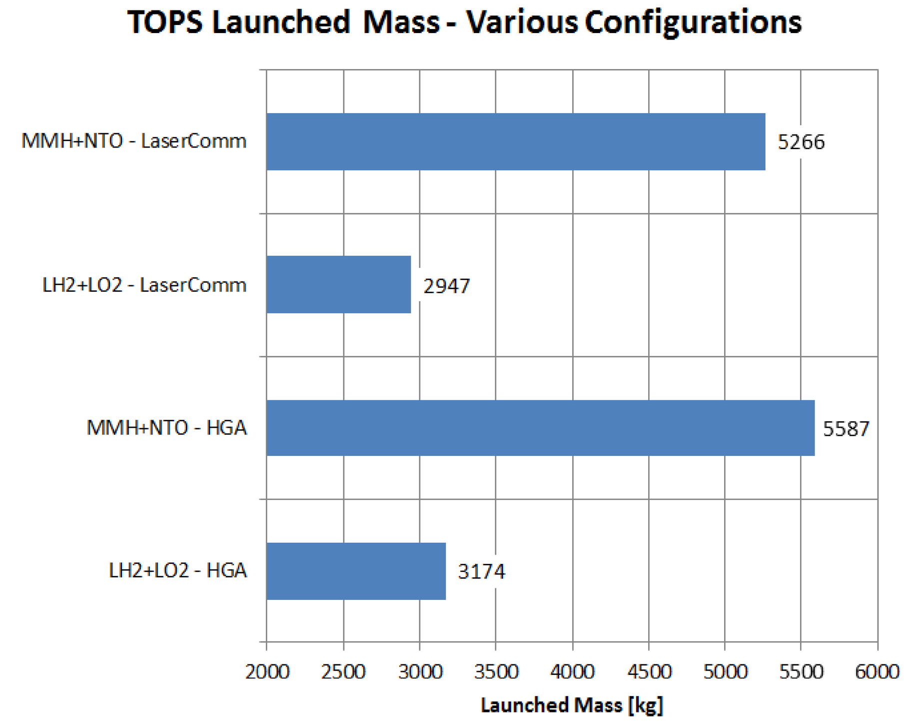








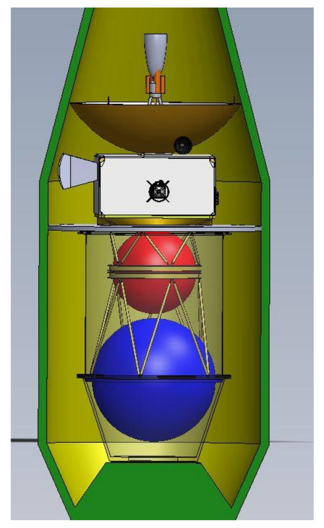
TOPS Launch Vehicle Mass



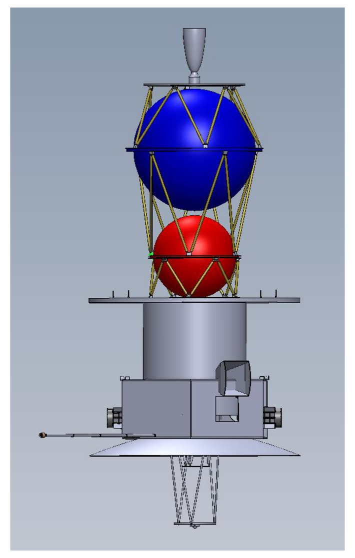
TOPS Design Study Results

- TOPS that is propelled by LH2+LO2 saves 43% in launched mass over TOPS that is propelled by MMH+NTO
- TOPS (with the 25% dry mass contingency) can be launched on an Atlas V 551 with a 8% launch mass margin.
- This mission does not close on any Atlas V vehicle if a standard hypergolic propulsion option is used.
- A LH2+LO2 cryogenic propelled TOPS mission could fit comfortably as a New Frontiers mission.
- Confirmed the basic viability and value of the LH2+LO2 cryo propulsion system.
- Provided a much better understanding of how to incorporate this kind of LH2+LO2 cryo propulsion into an actual mission.
- Generated a number of promising approaches for how the cryo propulsion could be further improved in terms of I_{sp}, mass, envelope, thermal control, and required electrical power.
- Efforts are underway to further reduce the TOPS expected dry mass to fit in even smaller launch vehicles without science reduction.

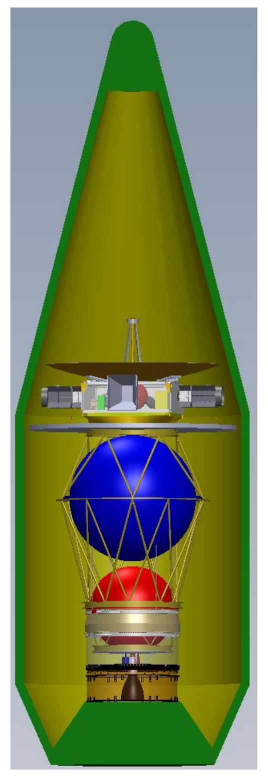
TOPS Configurations



Design 1

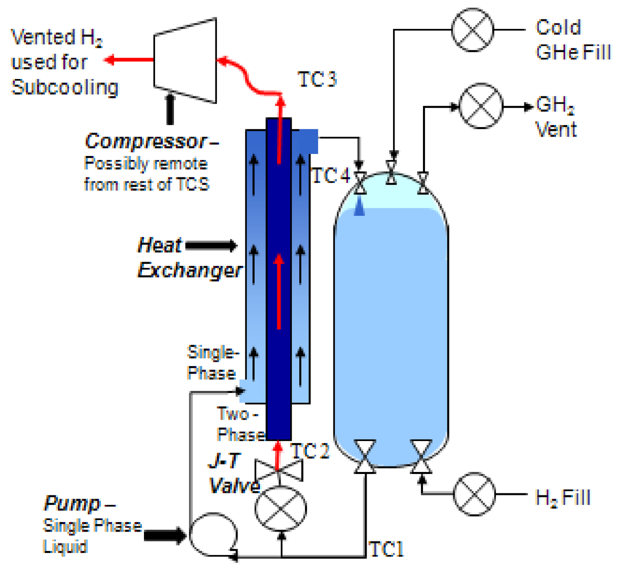


Design 2

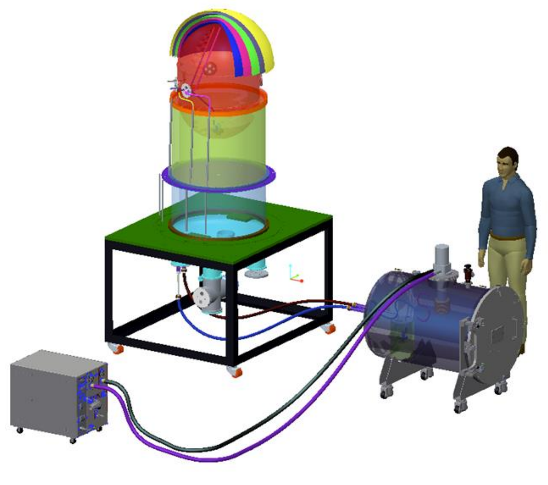


Design 3

Subcooling Systems

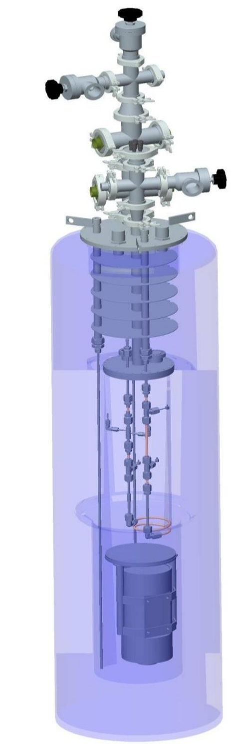


Launch Pad Ground Support Thermodynamic Cryogen Subcooler



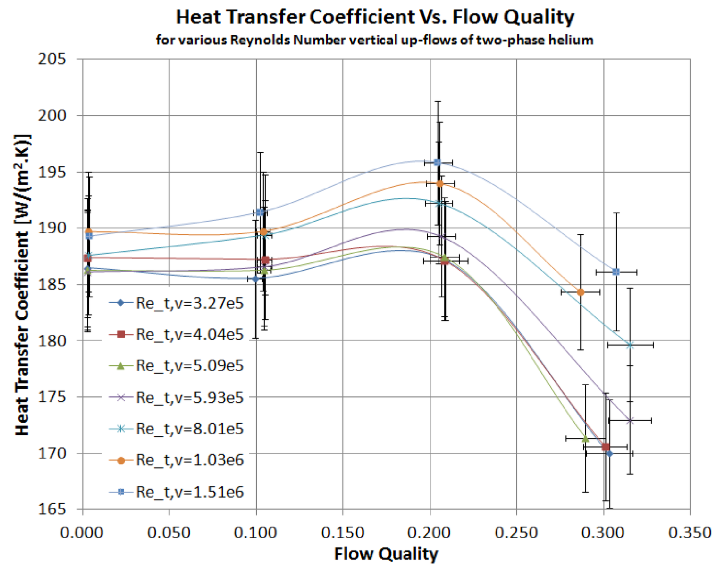
Launch Pad Ground Support Cryocooler

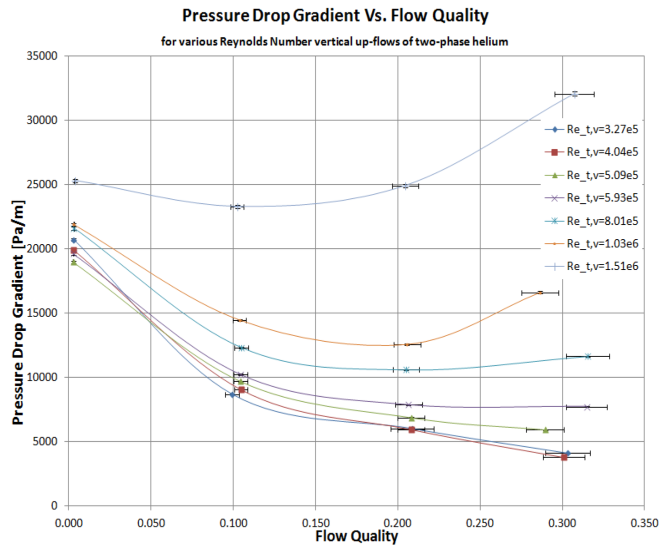
Subcooling Heat Exchanger Development

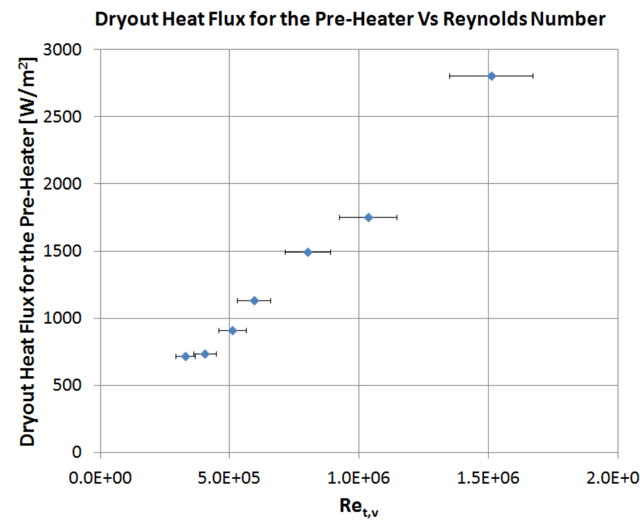


Experiment Results

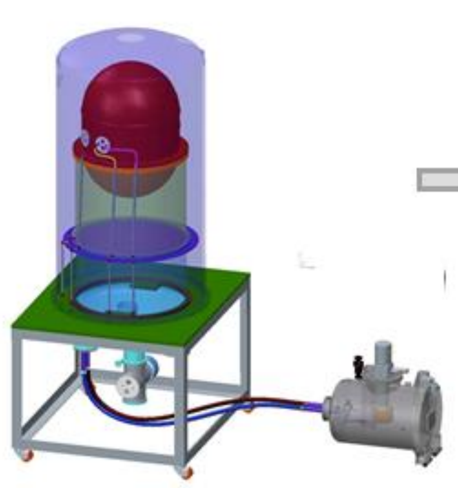
Data used to design Subcooling Hardware



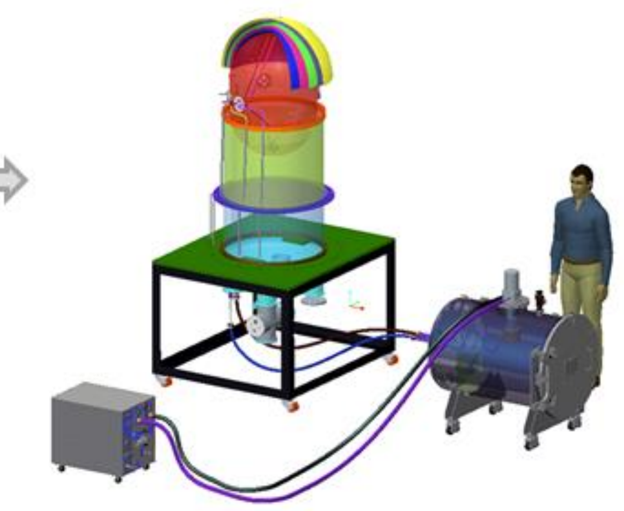




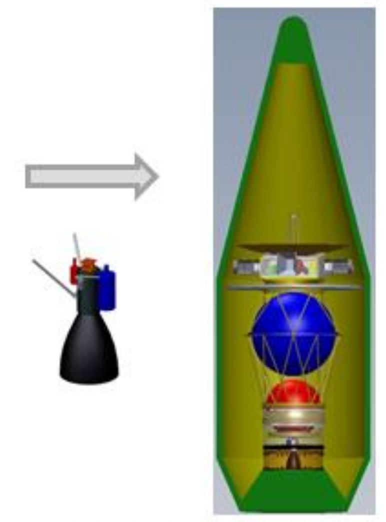
Future Work



Planetary Science : TRL 5



Planetary Science : TRL 6



Planetary Science : TRL 9

- LH2+LO2 propulsion system for planetary science missions will significantly enable or enhance many planetary science missions.
- Opens up new opportunities to explore outer planets and their moons by orbiting, landing and/or sample return, potentially without the necessity of proper planetary alignments for gravity assists.
- Increased science in the near term as well as providing a cost-effective, safe and clean technique for exploration of our solar system.

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